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Distribution and abundance of Atlantic cod from an acoustic survey of Bonavista Bay - Trinity Bay, Newfoundland during the fall of 1999

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Abstract

An acoustic survey was conducted during the fall of 1999 in the coastal waters of Bonavista Bay - Trinity Bay, Newfoundland. The survey area included water depths from the coastline to the 120 m contour. Echo integration along a series of parallel transects within the survey area provided distributional information, densities and a biomass estimate of Atlantic Cod. Comparisons were made with a similar survey conducted in the fall of 1996. The distribution of cod differed between the two surveys. A substantial aggregation of cod was detected in Smith Sound, Trinity Bay during the current survey which was not evident in 1996. It was concluded that there were no other large aggregations of cod, comparable to that in Smith Sound, within the survey area during the fall of 1999.

Résumé

Au cours de l'automne 1999, un relevé acoustique a été réalisé dans les eaux côtières de Bonavista Bay et de Trinity Bay, Terre-Neuve. Le secteur examiné comprenait les eaux s'étendant de la côte jusqu'à la ligne de contour de 120 mètres. Le relevé, par écho-intégration le long d'une série de transects parallèles à l'intérieur du secteur, a permis d'obtenir des données sur la distribution et la densité et la biomasse estimée de la morue de l'Atlantique. Des comparaisons ont été effectuées avec un relevé semblable réalisé au cours de l'automne 1996. La distribution de la morue de l'Atlantique variait selon les deux relevés. Une concentration appréciable notée dans le Smith Sound, Trinity Bay, lors du relevé de 1999 était absente au moment du relevé de 1996. On a conclu à l'absence, dans le secteur du relevé, d'autres concentrations importantes de morue, comparables à celle de Smith Sound, à l'automne de 1999.

Introduction

As part of the annual research program to assess Atlantic herring stocks in the Newfoundland Region, an acoustic survey was conducted during the fall of 1999 in the coastal waters of Bonavista Bay - Trinity Bay to estimate herring biomass. In addition to detecting pelagic herring schools, the acoustic system can detect and estimate the density of cod on or near the bottom (within certain limitations). This paper provides a biomass estimate of Atlantic cod, as detected during the 1999 survey, and compares it to an estimate from a comparable survey conducted in 1996 (Wheeler and Miller 1997). However, given the limitations of the acoustic system to detect fish close to the bottom, these estimates can only be considered as indices of abundance. The paper also compares distributions of cod from the two surveys. Caveats to the analyses are also discussed.

Methods

The survey design used in 1999 has been described in detail in stock assessment documents, most recently in Wheeler et al. (1999) and Anderson et al. (1998). In summary, the survey area was defined as the area from the coastline to the 120 m depth contour. This was divided into strata based upon geographical features and herring distribution patterns. A multi-start systematic design was used which allowed for the calculation of a survey-based variance estimate. Each stratum was sub-divided into blocks with equal number of parallel transects per block. Placement of transects were randomly selected in the first block of a stratum but were defined by this placement in the remaining blocks. Weighted cod densities were calculated for each block; a weighted mean density for the stratum was then calculated and extrapolated to the stratum area to estimate fish biomass. Strata estimates were summed to calculate a total biomass estimate for the survey area.

The survey was conducted from the *Three T's 1*, an 18 m chartered commercial herring purse seiner. The survey commenced in Trinity Bay on November 8, 1999 and terminated in Bonavista Bay on December 8, 1999.

A Femto Model 9001 acoustic data acquisition system was used in conjunction with a BioSonics Model 105 sounder and 120 kHz transducer (operating in single beam mode). The transducer, mounted in a v-fin, was deployed at a depth of approximately 3 m abeam of the starboard side of the vessel. The same acoustic system was used in the 1996 survey of the area (Wheeler and Miller 1997).

The acoustic system was calibrated prior to the survey on September 18, 1999. The calibration parameters were as follows:

Source Level / Receive Sensitivity:	42.25 dB
Fixed Receiver Gain:	11.31 dB
TVG Gain:	20 log R
Attenuation Coefficient:	0.03470 dB/m
Pulse Length:	0.4 ms
Average Beam Factor:	-29.4 dB

During the survey, a detailed log record was maintained for each transect and between transects. Observations were recorded of all fish concentrations (pelagic and groundfish) detected on the echogram and oscilloscope. Where concentrations warranted, and depth and weather conditions permitted, cod were sampled during the survey using jiggers and feathered hooks.

The acoustic data, as recorded in the detailed log, were subsequently edited using the Femto acoustic data editing system. Due to the irregular nature of the bottom topography throughout the survey nature, it was impossible to used a fixed bottom removal algorithm for all transects. Transects on which cod were detected were evaluated on a case by case basis; bottom removal criteria (ie. the size of the exclusion zone above the detected bottom), ranged from 0.5 to 2.0 m depending upon the bottom topography.

Only those fish concentrations considered to be cod, as viewed on the echogram, were included; pelagic herring concentrations were excluded from the analysis.

Acoustic back-scatter (m^2/sr) was converted to fish density (g/m^2) using the following target strength - fish length relationship calculated by Rose and Porter (1996):

$$T.S. = 20 \log L - 65.5$$

Target strength per fish was converted to target strength per unit fish weight using the following cod length - weight relationship (Shelton et. al. 1996):

$$\log W = 3.0879 * \log L - 5.2106$$

These are the same relationships that were used for the 1996 survey of the area. A more up-to-date target strength - fish length relationship is available (G. Rose, pers. comm.) but was not used so that comparisons between the 1996 and 1999 surveys could be made.

Formulas used to calculate mean densities, variances, and biomass estimates remained unchanged from previous surveys and are described in Wheeler (1991).

For the purpose of plotting cod distributions, mean densities (g/m^2) were calculated per ten second interval along each transect.

Results

Cod were sampled by jiggers and feathered hooks from 22 different locations throughout the survey area (Table 1), 18 in Trinity Bay and 4 in Bonavista Bay. Sample sizes from each location ranged from 1 - 48 fish. At all sampling locations, cod was the only species caught; most cod were caught in close proximity to the bottom. In Trinity Bay, the mean length of the sampled cod was 63.3 cm (n = 287); in Bonavista Bay, it was 51.5 cm (n = 18). As there were so few fish sampled in Bonavista Bay, a combined mean length of 62.6 cm (n = 305) was calculated for the entire survey area (Figure 1) and was used to calculate target strength (Figure 1). The calculated target strength was -63.75 dB/g. The same process was used to calculate the target strength for the 1996 survey of the area (Wheeler and Miller 1997).

During the survey, 291 transects were surveyed from Grates Point, Trinity Bay to Shoe Cove Point, Bonavista Bay (Figures 2 and 3). The total length of transects was 489 n.mi.

Although cod were distributed widely along transects throughout the survey area and were detected in 955 (3.3%) of 29100 ten second intervals, this represented a decrease in distribution from the 1996 survey when cod were detected in 5.9% of the ten second intervals (Wheeler and Miller 1997). Cod densities within these intervals ranged from 0.000 - 1.923 kg/m^2, with a mean density of 0.003 kg/m^2. Cod were most prevalent in Smith Sound, Trinity Bay and in the northern portion of Bonavista Bay.

Cod were distributed in water depths as shallow as 10 m throughout the survey area (Figure 4). However, most occurred in water depths of 20 - 40 m, with peak densities in depths of approximately 20 m. Approximately 95% of the cod densities were detected in water depths less than 75 m.

A biomass estimate of 5100 t was derived from the survey area (Table 2), 3350 t (66%) in Trinity Bay and 1750 t (34%) in Bonavista Bay. The biomass estimate was comparable to that derived from the 1996 survey (Figure 6). Cod were detected in 16 of the 20 surveyed strata; the Smith Sound stratum (stratum #38) accounted for 53% of the estimated biomass.

Cod in Smith Sound were mainly distributed in the inner part of the Sound (Figure 5) in water depths of 20 - 40 m. Biological samples within the Sound ranged in length from 52 - 98 cm.

Discussion

This represents the third time since 1996 that an acoustic biomass estimate for cod has been calculated from a fall survey of the coastal waters of Bonavista - Trinity Bay. As already mentioned, a comparable acoustic survey was conducted in 1996 (Wheeler and Miller 1997). Assuming that the behavior of cod (in relation to their distribution off bottom) was similar in 1996 and 1999, the results of these two surveys should be directly comparable as the survey areas, survey timing, and acoustic equipment were all identical. A third acoustic cod biomass estimate of the area was calculated from the 1997 Div. 3KL inshore acoustic survey (Anderson et al. 1998). Comparisons with this survey are not as valid as the survey area in 1997 included greater water depths and a different acoustic system (38 kHz) was used.

Anderson et al. (1998) identified several exclusion zones, variable in area, which could not be acoustically surveyed. These included an area of approximately one meter above the bottom, near shore shallow water areas inaccessible to the survey vessel, areas of steep bottom topography affected by acoustic shadowing, and a surface zone above the transducer. These are common to all three of the surveys described above but are highly variable in nature. In addition, other sources of variance include target strength, survey design, biological data, calibration of acoustic equipment, and vessel avoidance. These multiple and highly variable sources of variance make it difficult to calculate an accurate cod biomass estimate. However, for comparable surveys, the biomass estimates can be used as indices of abundance.

The 1996 and 1999 survey results (Figure 6) indicate that in relative terms, the overall cod biomass for the survey area did not change. There was a shift in the distribution of cod in the two surveys, in 1996 more fish were detected in Bonavista Bay than in Trinity Bay; in 1999, the reverse was true. In 1997, cod were equally distributed between the two bays (Figure 7). The biomass estimate from the 1997 survey was also approximately twice that of the 1996 and 1999 surveys. This difference highlights the problems in comparing biomass estimates from surveys where the area surveyed and acoustic equipment used were different.

The distribution of cod was different between the surveys. In the current survey, there was a substantial aggregation of fish in Smith Sound, Trinity Bay (Figure 5), approximately 2700 t, which accounted for half of the biomass estimate from the survey. Cod were not aggregated to the same degree in Smith Sound in 1996, when the biomass estimate for the stratum was approximately 1000 t (Wheeler and Miller 1997). Similarly, in 1997, when the overall biomass estimate from the survey was approximately double, the biomass estimate for the Smith Sound stratum was less than 1000 t (Anderson et al. 1998). Previous acoustic surveys have shown there to be large aggregations of cod within Smith Sound in the overwintering and early spring period (Porter et al. 1998). Results from the fall surveys indicate a seasonal movement of fish in and out of the Sound, with fish moving into the Sound in the late fall, at or about the time of the 1999 survey.

Although cod were distributed widely during the 1999 survey, they were distributed in 55% fewer acoustic sampling intervals (10 sec.) than in 1996. The aggregation of cod detected in the inner part of Smith Sound was the only substantial aggregation detected during the survey. This should not be interpreted to mean that there were no cod elsewhere; however, it does suggest that there were no large aggregations elsewhere. If other large aggregations existed within the survey area and behaved in a similar manner to the fish within Smith Sound, they would have been detected by the acoustic system.

Similar to the 1996 survey, cod continued to be detected in very shallow water during the 1999 fall survey. Although the acoustic system sampled to a depth of 150 m, peak cod densities occurred in 20 m. This is even shallower than in 1996 when peak densities occurred in 45 m. This depth distribution was very evident in Smith Sound where cod were distributed along the slopes in 20 m to 40 m but were not detected in deeper water.

Conclusions

- Cod biomass estimates derived from acoustic surveys designed for herring should be considered as relative indices of abundance.
- The relative abundance of cod in the Bonavista Bay - Trinity Bay survey area did not change from 1996 to 1999.
- The distribution of cod in the 1996 and 1999 surveys differed; in 1996, more cod were detected in Bonavista Bay than in Trinity Bay. In 1999, the reverse was true.
- In the fall of 1999, a substantial aggregation of cod was detected in Smith Sound, Trinity Bay, which was not evident in the fall of 1996 or 1997. As substantial

aggregations have been detected within the Sound during the overwintering period, this indicates a seasonal movement of cod into the Sound during the late fall.

- It is unlikely that there were other large aggregations of cod, comparable to that in Smith Sound, within the survey area during the fall of 1999.

- Cod were distributed in shallow water within the survey area with peak densities in water depths of 20 m.

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Table 1. Cod sampling details (jiggers and feathered hooks), Three T's 1 Trip #1, Bonavista Bay - Trinity Bay, 1999.

Date	Stratum	Geographical Location	Latitude	Longitude	Mean Lgt. (cm)	Length Range (cm) Min.	Max.	n
Nov. 11	44	Tickle Harbour Point	47.40.605	53.40.299	30	24	37	23
Nov. 12	43	Bull Arm	47.48.958	53.51.008	50	50	50	1
Nov. 12	42	Deer Harbour	47.53.610	53.43.538	57	50	66	6
Nov. 12	42	St. Jones Harbour	47.55.468	53.42.525	32	25	42	5
Nov. 13	41	St. Jones Within	48.02.625	53.44.714	31	31	31	1
Nov. 13	41	Hillview	48.01.622	53.56.249	51	40	61	2
Nov. 13	41	Leonards Cove	48.00.069	53.49.840	50	48	51	2
Nov. 14	40	Clarenville	48.11.105	53.57.138	73	70	75	4
Nov. 15	38	British Harbour	48.15.161	53.30.344	69	56	81	16
Nov. 15	38	Indian Island	48.12.848	53.32.021	65	57	71	6
Nov. 15	38	Long Harbour	48.11.168	53.35.684	64	52	75	16
Nov. 15	38	Nut Cove	48.10.430	53.40.319	63	58	68	6
Nov. 16	38	Petley	48.09.375	53.44.544	66	53	76	35
Nov. 16	38	Waterville	48.11.663	53.46.896	69	56	97	32
Nov. 16	38	Snooks Harbour	48.10.182	53.50.859	68	56	98	39
Nov. 16	38	Burnt Brook Cove	48.12.702	53.53.416	71	55	86	16
Nov. 16	38	Daltons Head	48.11.313	53.49.710	71	58	86	48
Nov. 16	37	Trinity Harbour	48.22.940	53.22.000	63	51	69	14
Nov. 22	31	Ratchet Cove	48.36.570	53.44.050	61	44	78	15
Nov. 30	28	Little Content	48.50.250	53.51.060	32	32	32	1
Dec. 5	27	Lewis Island	48.57.810	53.50.040	48	22	58	6
Dec. 6	27	Cat Island	48.01.440	53.42.960	55	43	65	11
				All Sets	63	22	98	305

Table 2. Bonavista Bay - Trinity Bay cod biomass estimate by stratum and bay from the 1999 herring acoustic survey.

	Stratum	Stratum Area (sq.km.)	Mean Density (g./sq.m.)	Stratum Biomass (t)
Trinity Bay	46	186	0.8459	157
	45	95	0.4348	41
	44	164	0.5694	93
	43	111	1.4157	157
	42	181	0.6025	109
	41	54	1.5608	84
	40	77	0.1752	13
	39	92	0.0000	0
	38	92	29.2548	2691
	37	141	0.0000	0
	36	771	0.0000	0
Bonavista Bay	35	297	0.1224	36
	34	134	0.0346	5
	33	66	0.3520	23
	32	72	0.0000	0
	31	120	1.8495	222
	30	280	0.4789	134
	29	208	3.0511	635
	28	200	0.9910	198
	27	277	1.7805	493
			Total Biomass =	5094
			S.E. =	1011
			C.V. =	0.199

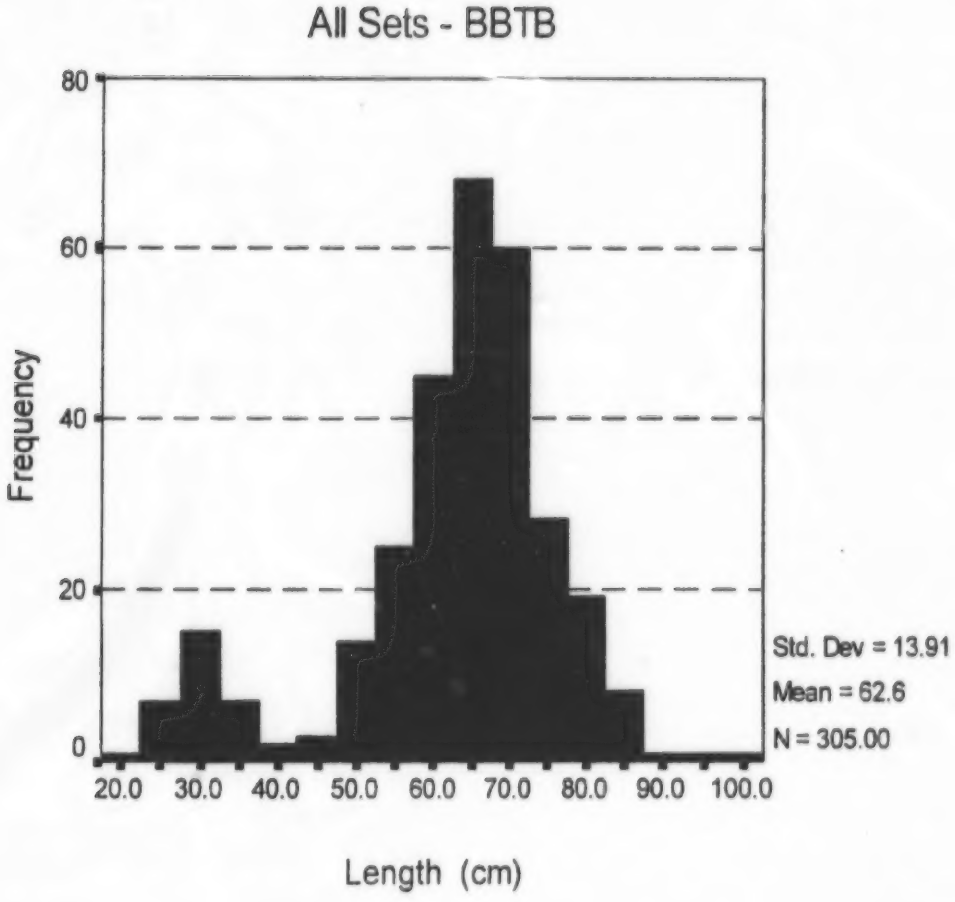

Figure 1. Length distribution of cod sampled by jiggers and feather hooks in Trinity Bay and Bonavista Bay during the 1999 herring acoustic survey.

Figure 2. Distributions and relative densities of cod on and between transects in Trinity Bay during the 1999 herring acoustic survey.

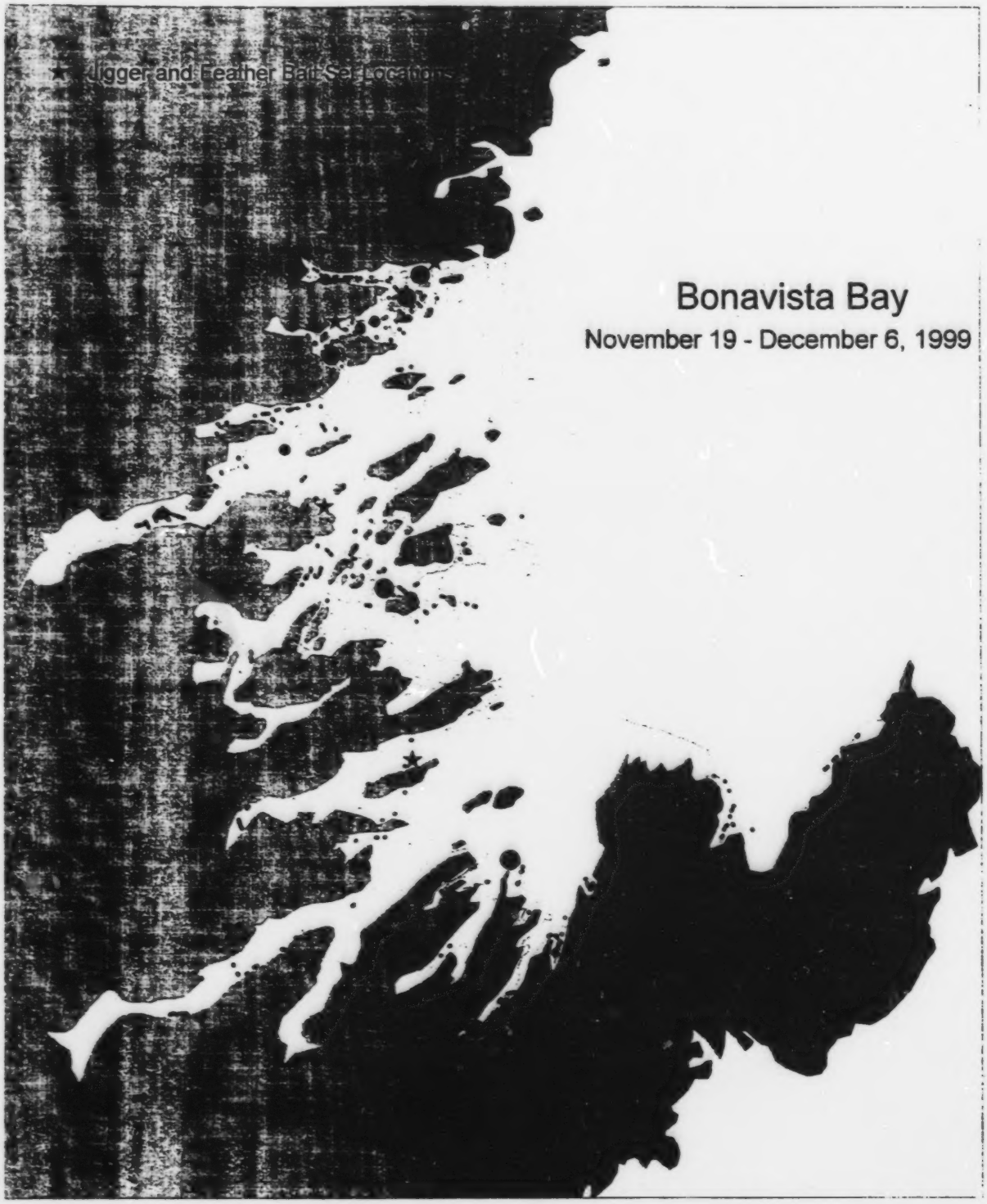

Figure 3. Distributions and relative densities of cod on and between transects in Bonavista Bay during the 1999 herring acoustic survey.

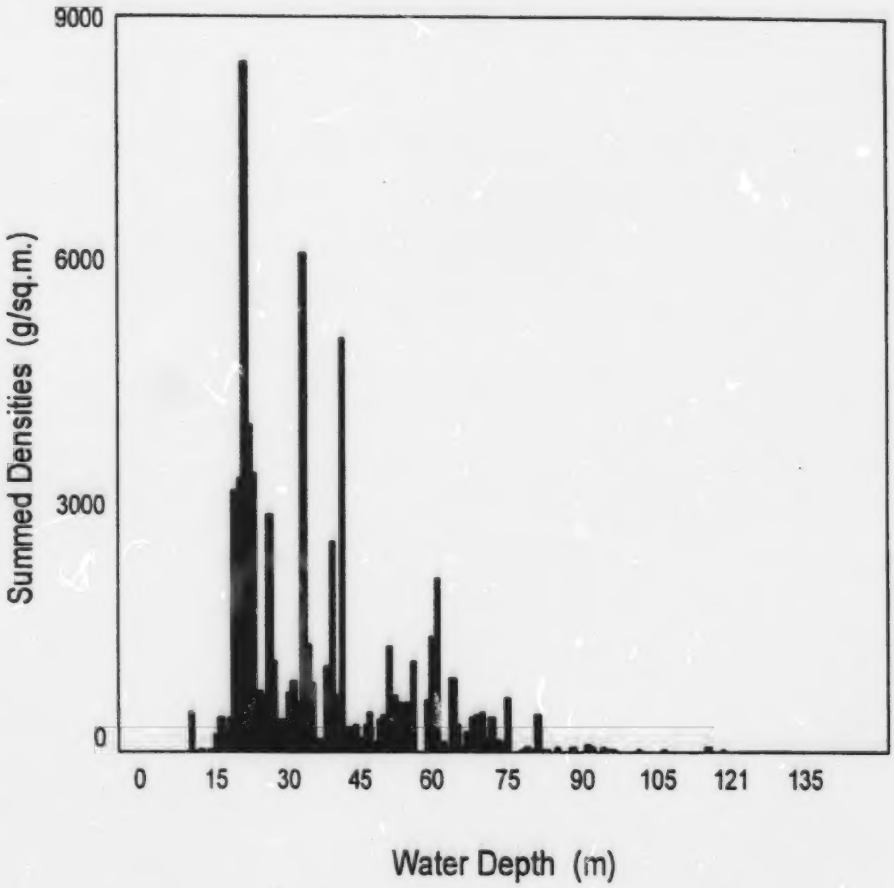

Figure 4. Distribution of cod densities, by water depth, as detected on transects in Bonavista Bay - Trinity Bay during the 1999 herring acoustic survey.

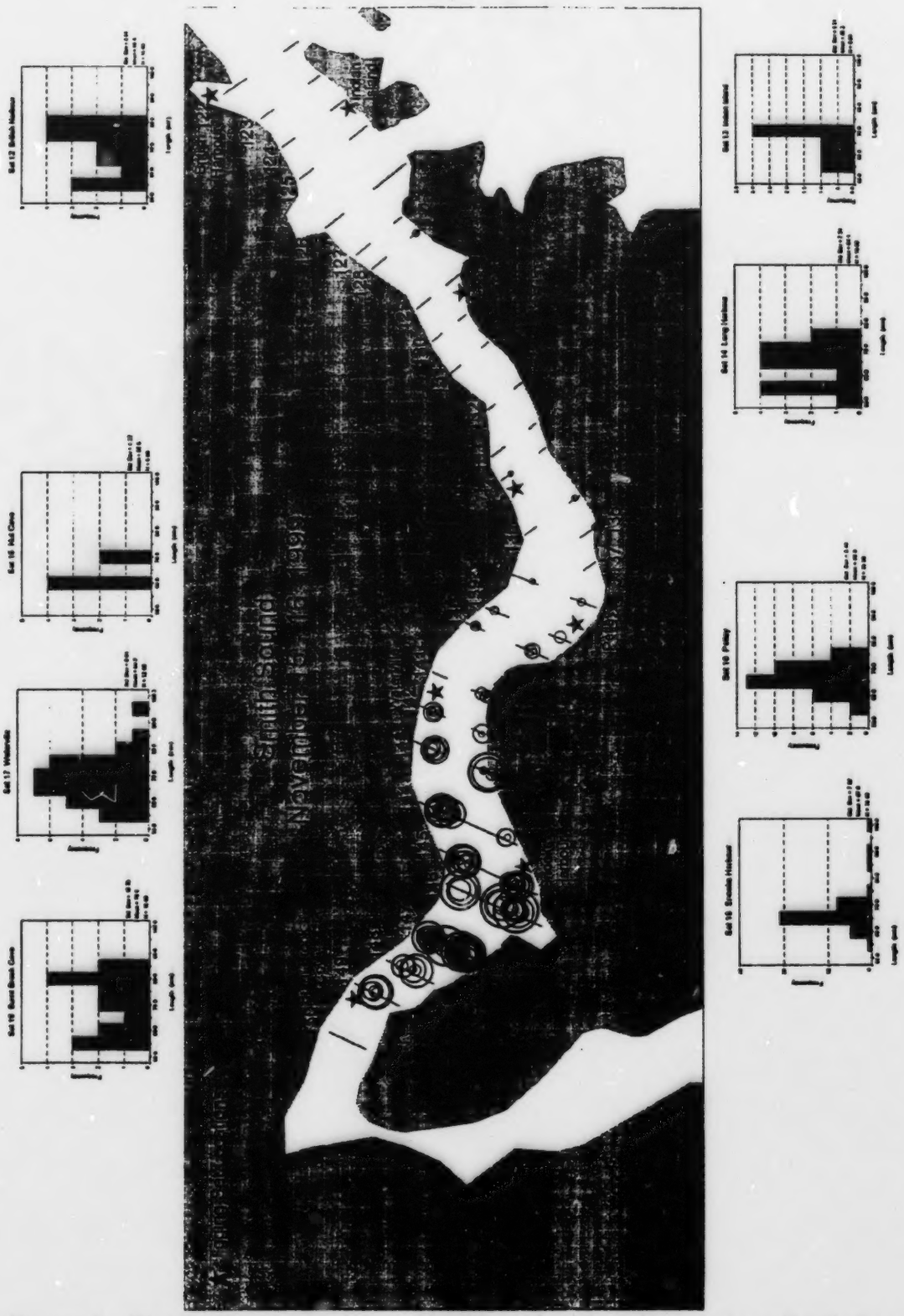

Figure 5. Distribution and relative densities of cod on transects in Smith Sound during the 1999 herring acoustic survey.

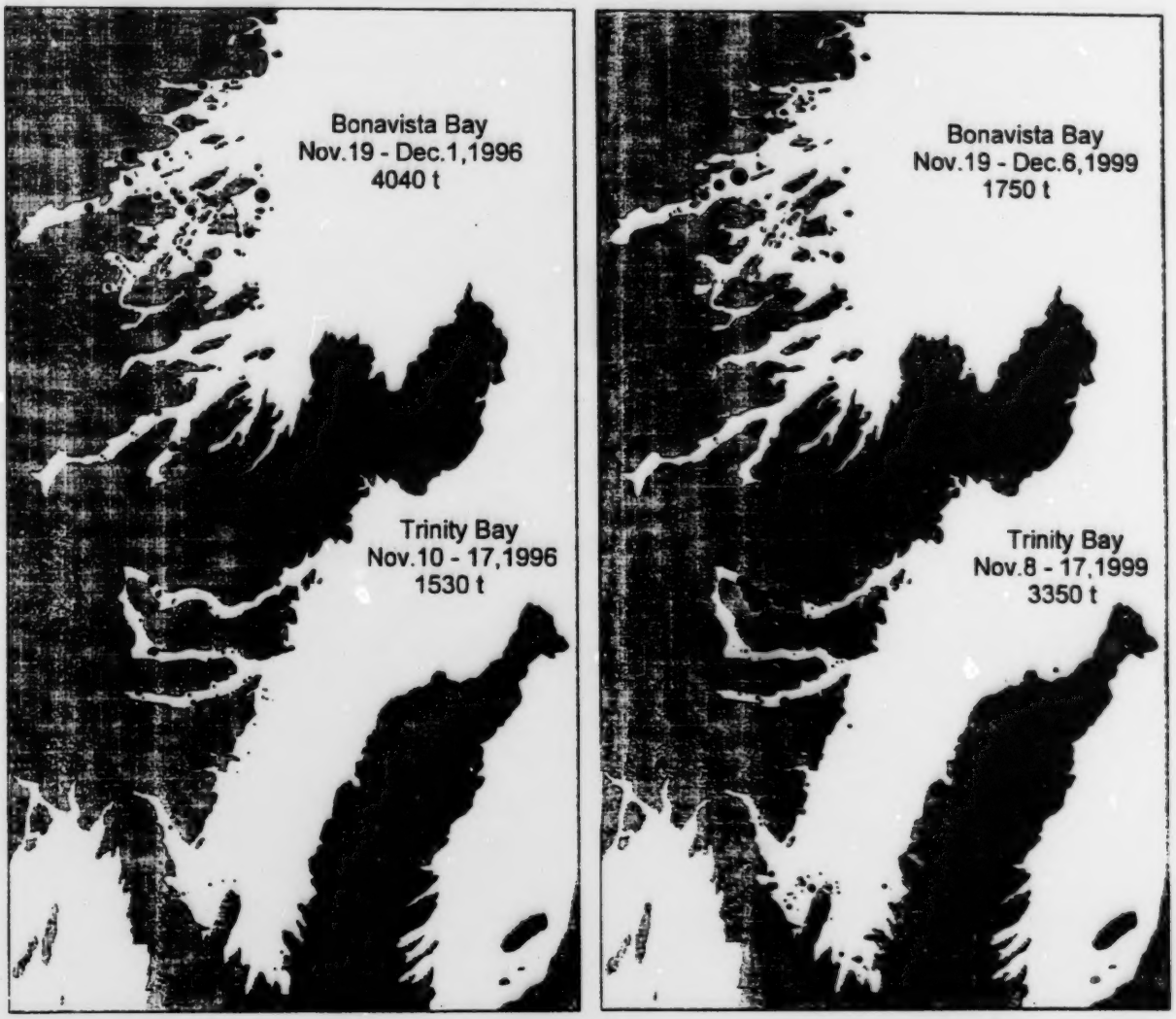

Figure 6. Comparison of distribution, relative densities (same scale), and biomass estimates of cod in Trinity Bay and Bonavista Bay from 1996 and 1999 herring acoustic surveys.

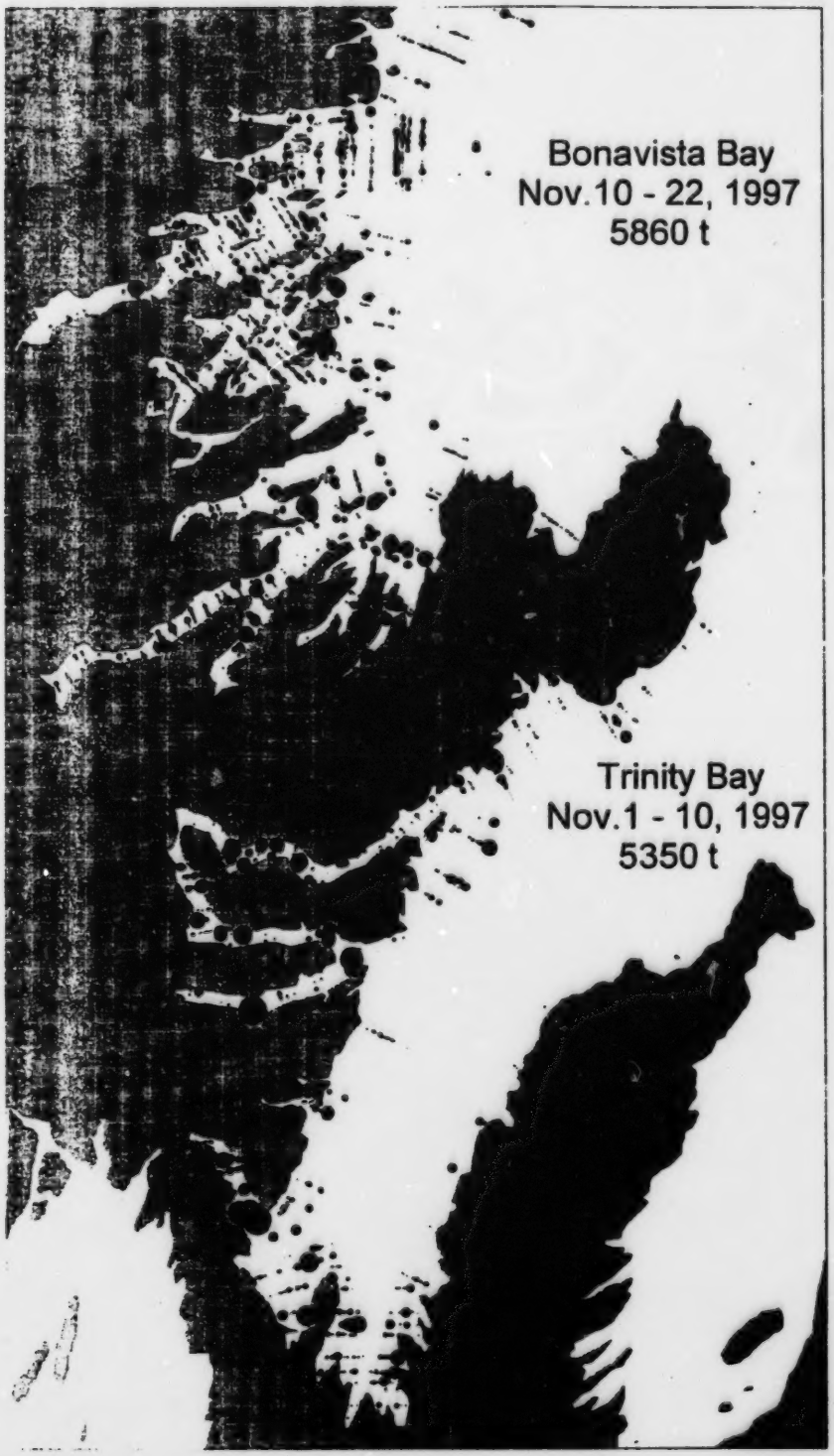

Figure 7. Distribution, relative densities, and biomass estimates of cod in Trinity Bay and Bonavista Bay from the 1997 Div. 3KL inshore acoustic survey.